Advanced Component Development to Enable Low-Mass, Low-Power High Frequency Radiometers for Coastal Wet-Tropospheric Correction on SWOT

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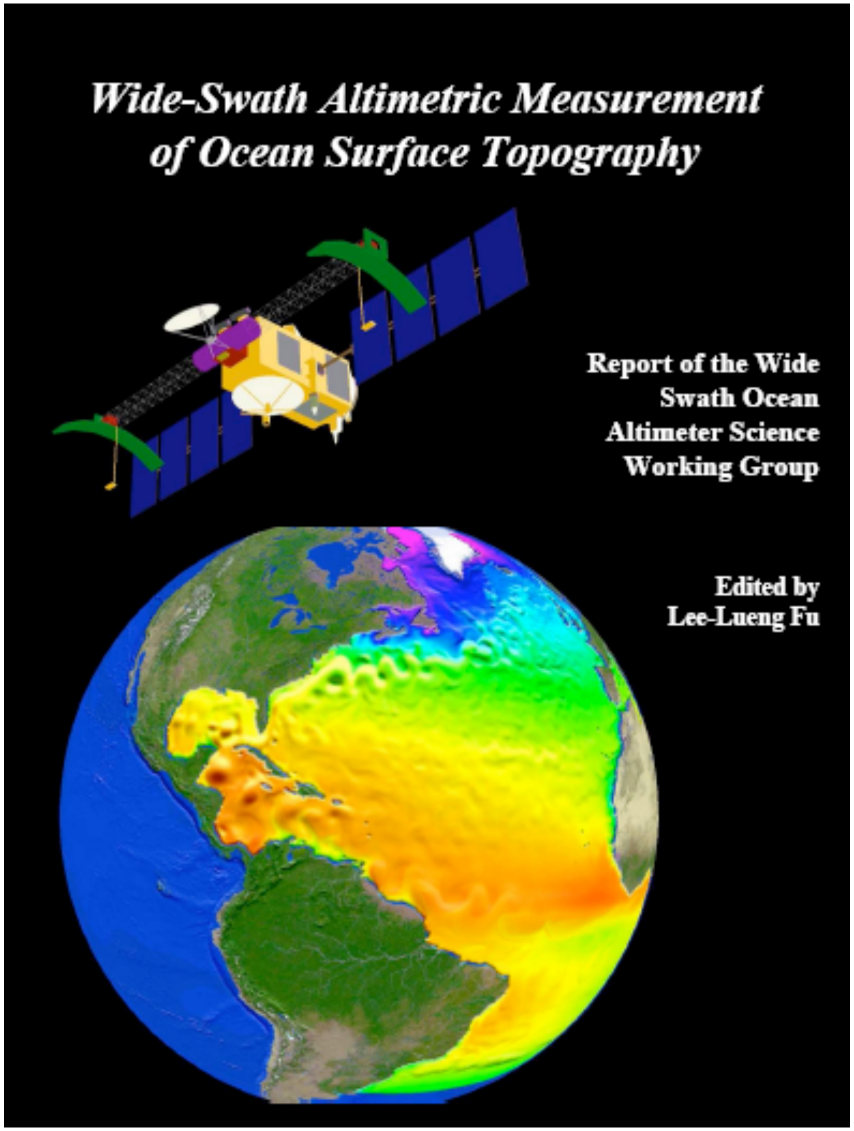
Introduction



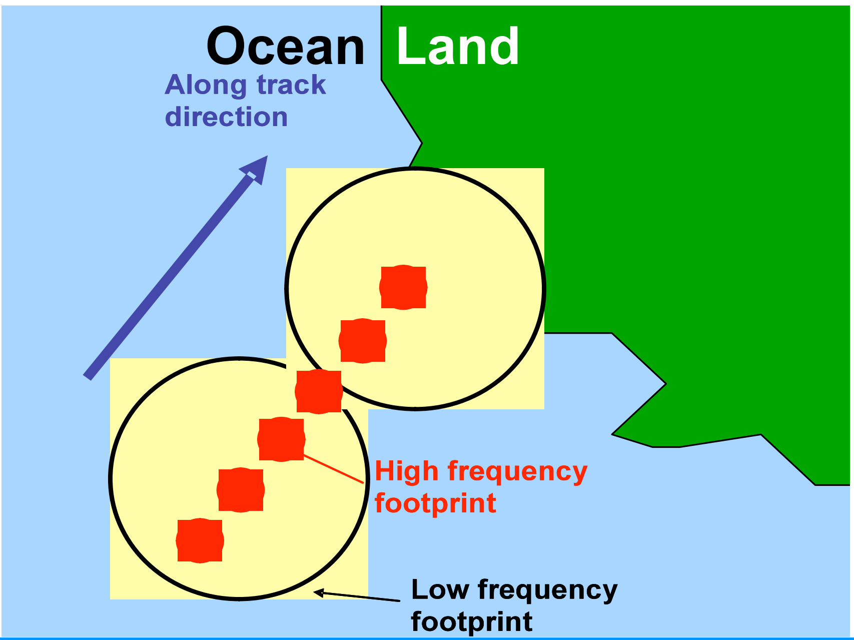
Critical microwave component and receiver technologies are under development to reduce the risk, cost, volume, mass, and development time for a high-frequency microwave radiometer that is needed to enable wet-tropospheric correction in the coastal zone on the Surface Water and Ocean Topography (SWOT) Mission recommend as a Tier 2 mission by the U.S. National Research Council's Earth Science Decadal Survey.

Current ACT Project

- Advanced Component Technology (ACT) project started in February 2009.
- Thanks to NASA ESTO for their continuing support!

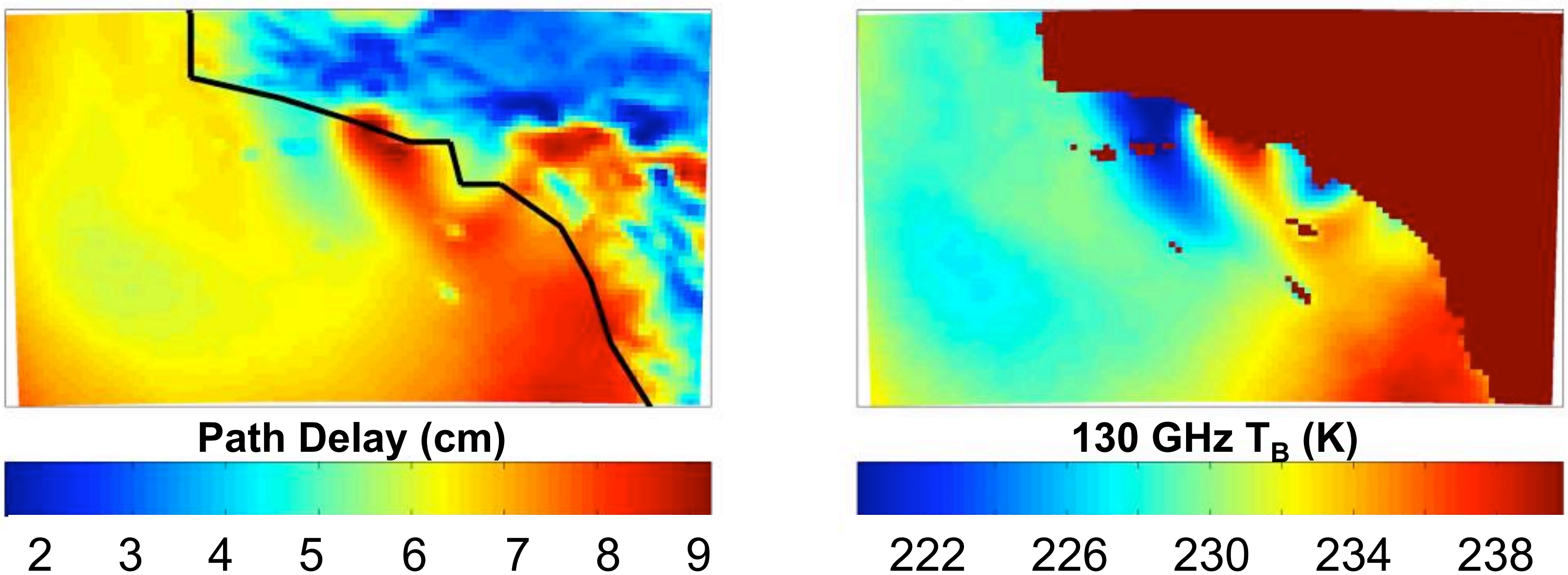
Scientific Motivation

- Conventional altimeters include a nadir-viewing co-located 18-37 GHz microwave radiometer to measure wet tropospheric path delay.
  - Reduced accuracy in coastal zone (within ~50 km from land)
  - Does not provide wet path delay over land
- Addition of higher-frequency microwave channels to Jason-1 and OSTM/Jason-2 radiometer will improve retrievals in coastal regions and may enable retrievals over land.



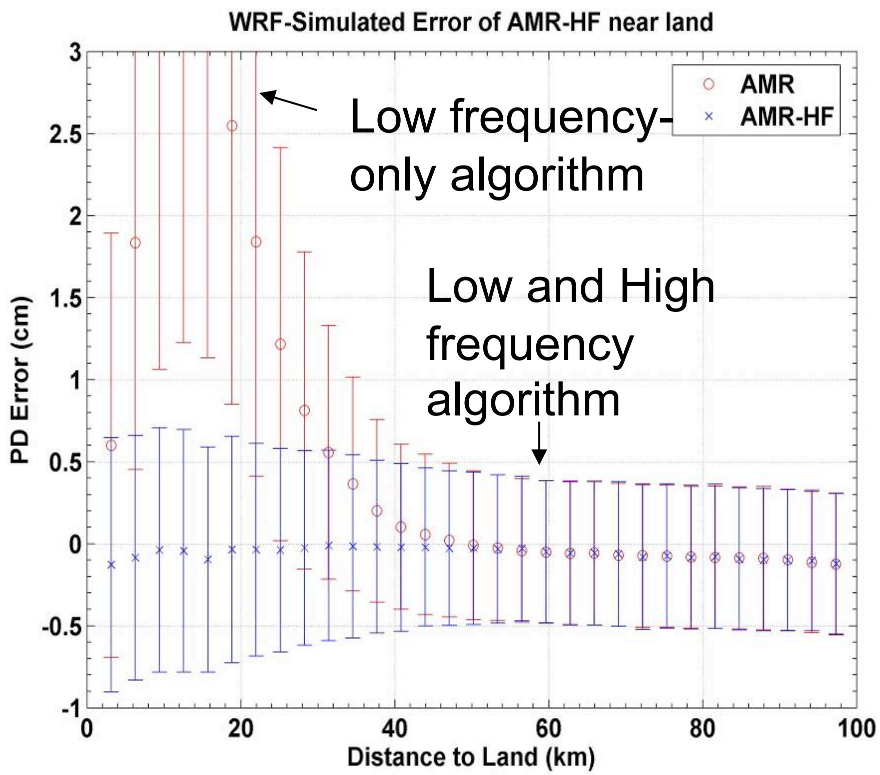
- High-frequency window channels at 92, 130 and 166 GHz are optimal for improving performance in coastal region.
- Channels near 183 GHz water vapor line are ideal for over-land retrievals.

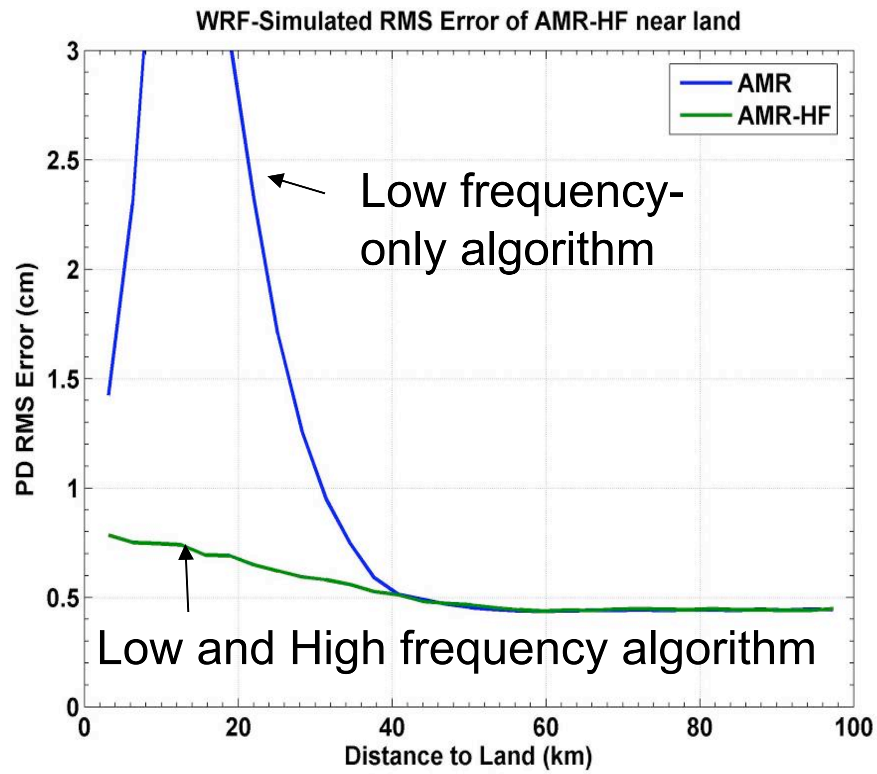
A radiative transfer simulation coupled with a high-resolution Weather Research and Forecasting (WRF) model has been implemented to assess retrieval performance and determine instrument requirements.



Example radiometer simulator output off Southern California

SWOT Mission Concept Study Results



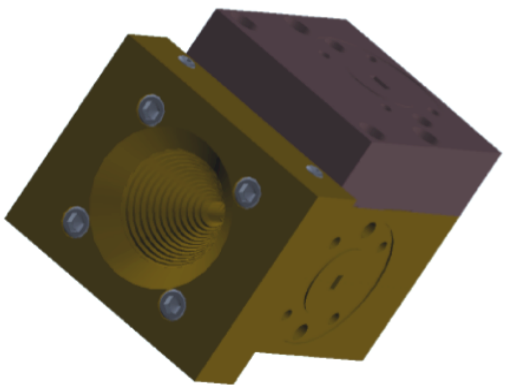


High-resolution WRF model results show reduced wet path-delay error using both low-frequency (18-37 GHz) and high-frequency (90-170 GHz) radiometer channels.

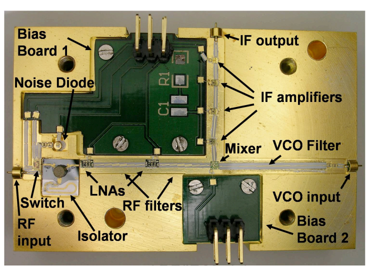
Objectives

- Develop low-power, low-mass and small-volume direct-detection millimeter wave receivers with integrated calibration sources covering frequencies from 90 to 170 GHz
- Design and fabricate a tri-frequency feed horn covering 90 to 170 GHz
- Design and fabricate a PIN-diode switch for calibration that can be integrated into the receiver front end
- Develop and test high-Excess Noise Ratio (ENR) noise sources from 100 to 170 GHz
- Integrate and test components in MMIC-based low-mass, low-power, small-volume radiometer at 92, 130 and 166 GHz with the multi-frequency feed horn

Requirements



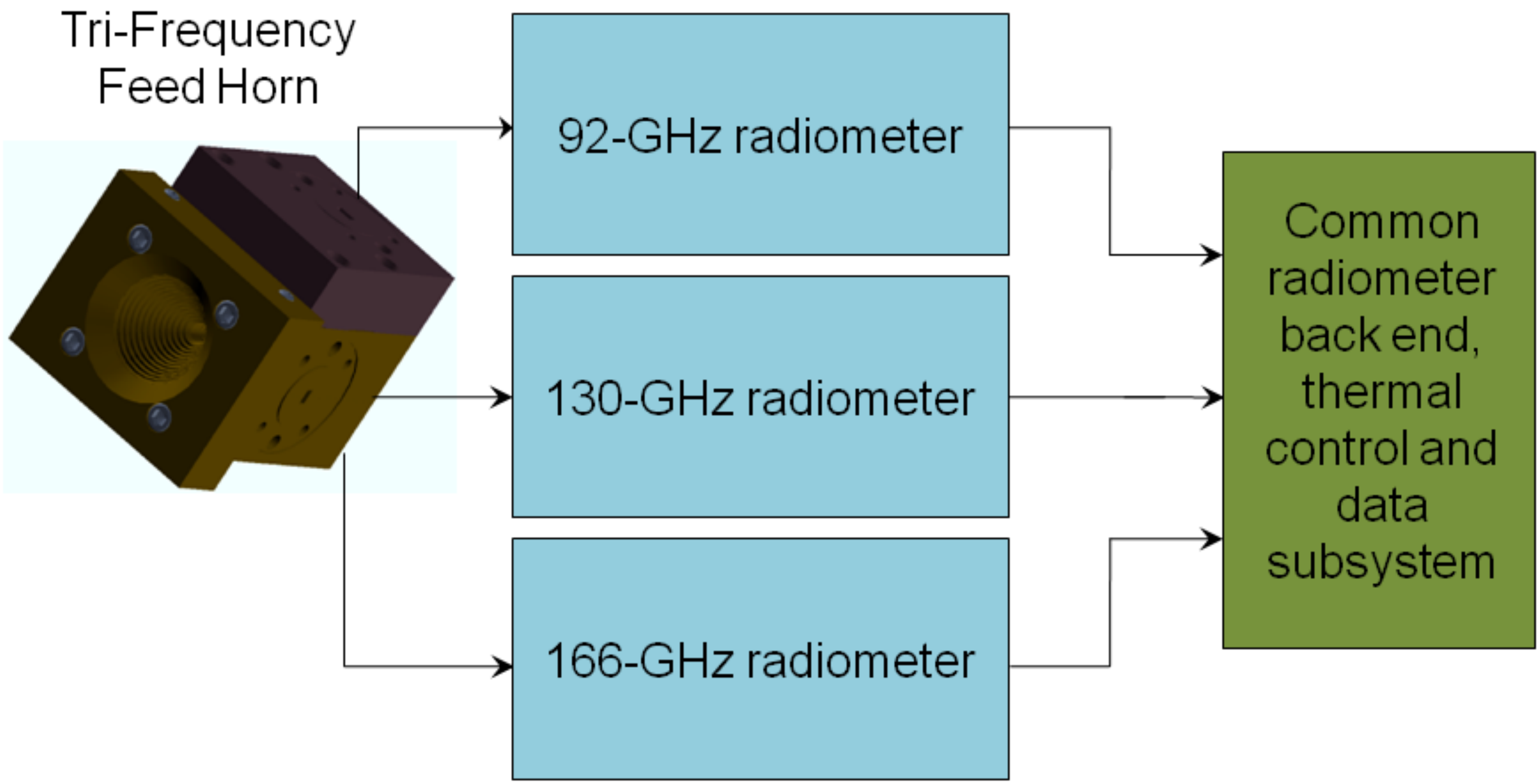
Key Antenna Subsystem RF Requirements	
Center frequencies	92, 130 and 166* GHz
Bandwidths	10 GHz
Port-to-port isolation	> 20 dB
Return loss	> 15 dB
Insertion loss	< 0.75 dB



Key Receiver RF Requirements	
Center frequencies	92, 130 and 166 GHz
Bandwidths	5 GHz
Noise Temperature	< 1300 K
Return loss	> 15 dB

*Note: *We will attempt to push all 166 GHz designs to accommodate 183 GHz sounding channels as closely as possible.*

System Block Diagram



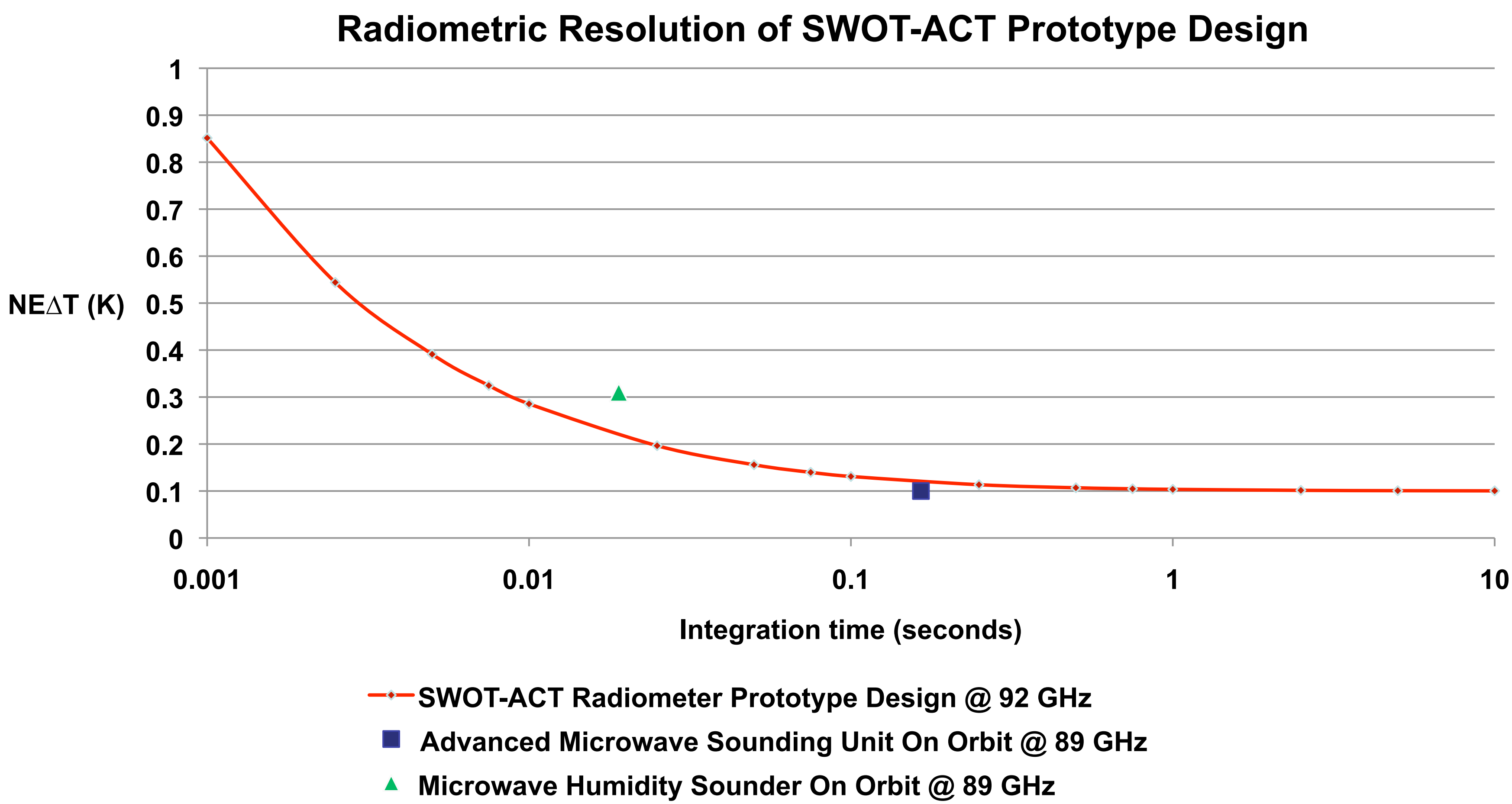
92 GHz Receiver Noise Figure

- Easily meets specification of Receiver Noise Temperature < 1300 K

Component	Vendor	Gain (dB)	Noise Figure (dB)	Cumulative Noise Temperature (K)
Directional Coupler	Dorado	-0.5	0.5	35
Isolator	Raditek	-0.5	0.5	75
Waveguide-to-Microstrip Transition	CSU/MSL	-0.25	0.3	97
Switch	M/A-Com	-1.2	1.2	220
Low-Noise Amplifier	HRL Labs	30	3.0	727
Band-Definition Filter	CSU/MSL	-1.5	1.5	727

Receiver Noise Factor	3.5
Receiver Noise Figure (dB)	5.5
Receiver Noise Temperature (K)	727.4

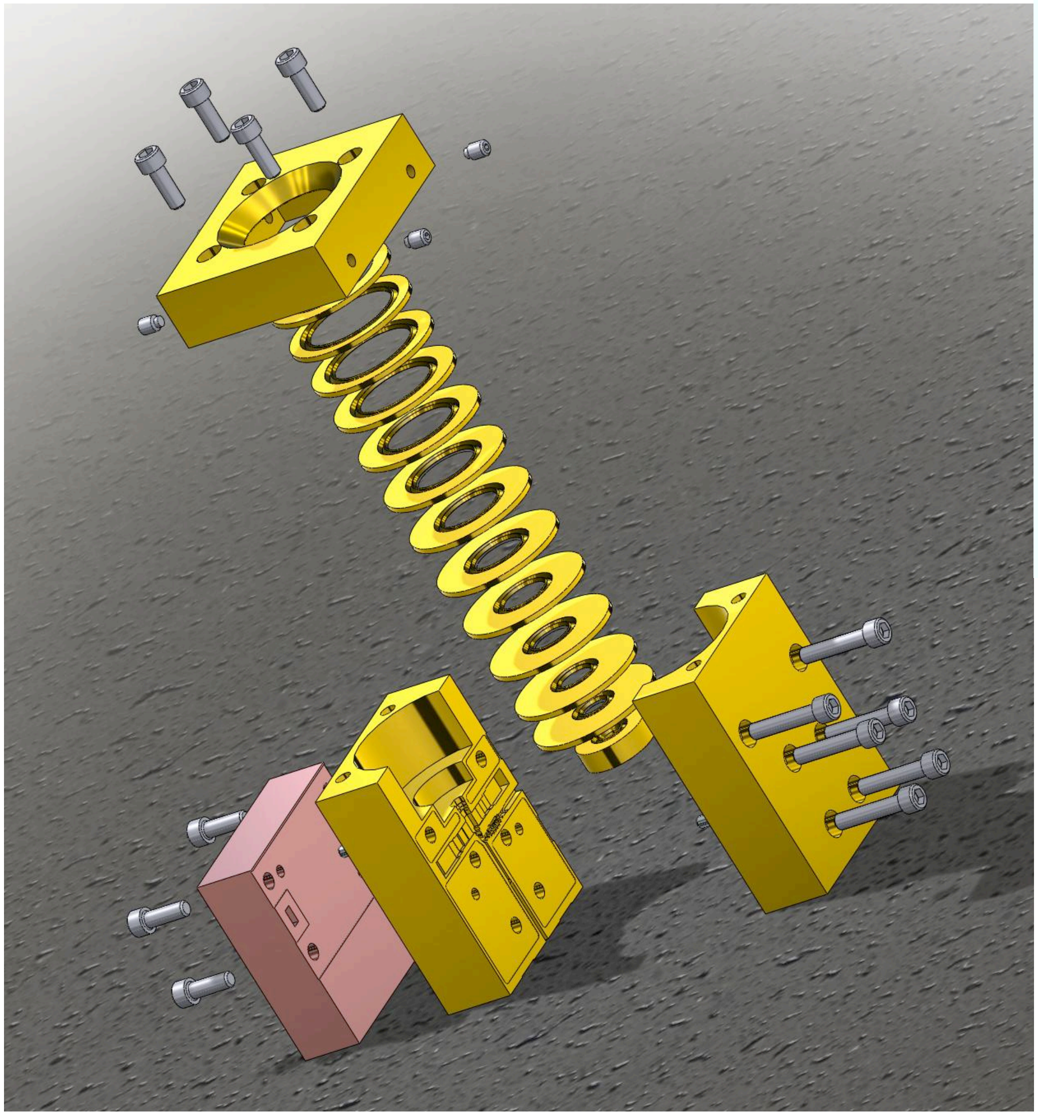
92 GHz Performance Analysis

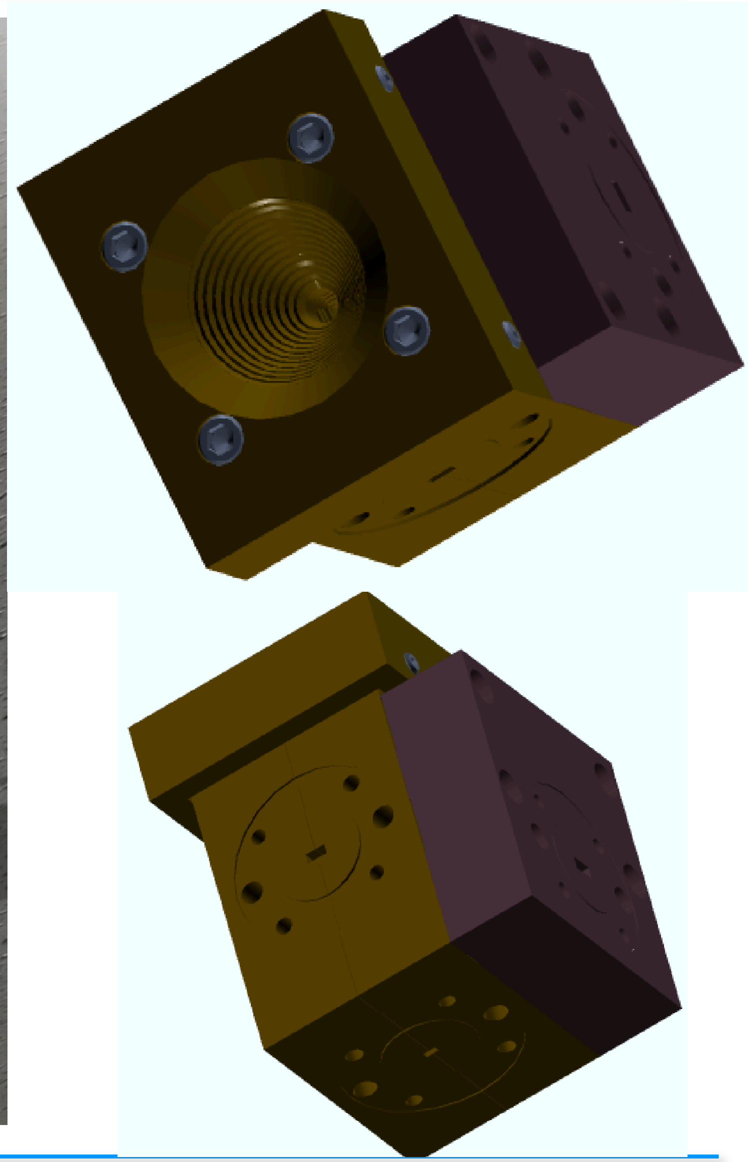


92 GHz Receiver Design

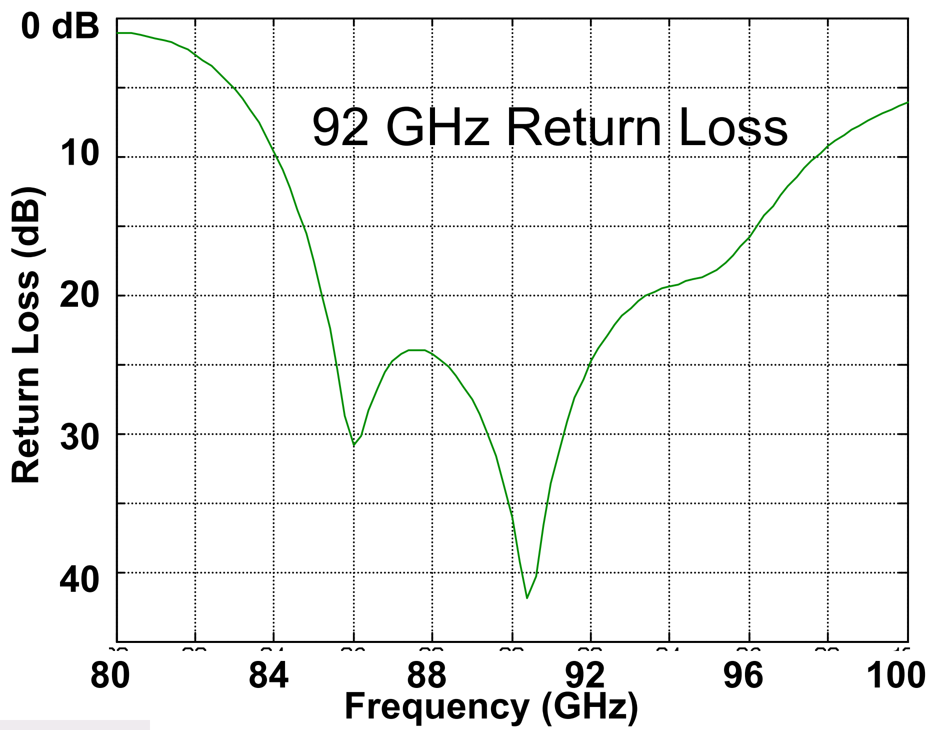
- Commercially-available off-the-shelf components
  - Waveguide-based components: Isolator and directional coupler
  - MMIC components: PIN-diode switch, LNA and detector
- Passive components custom-designed at CSU
  - RF bandpass filters, waveguide-to-microstrip transition and matched load
- MMIC multi-chip module custom-designed at CSU
- Noise diode packaged at JPL
- PIN-diode switches designed at JPL and fabricated at Northrup Grumman
- Three-frequency feed horn designed at JPL

Three-Frequency Horn Design

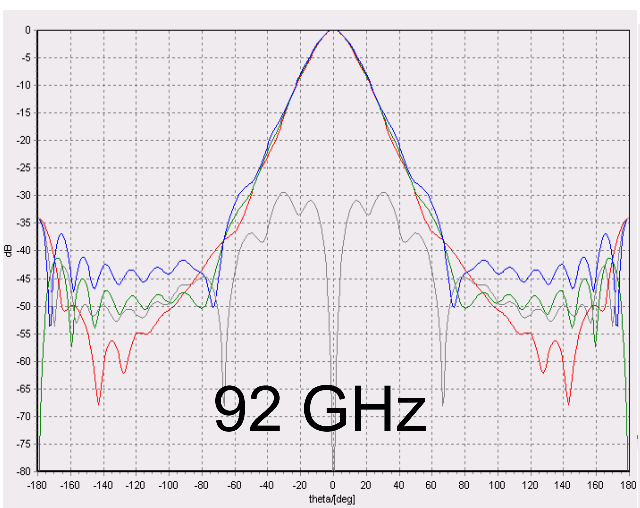


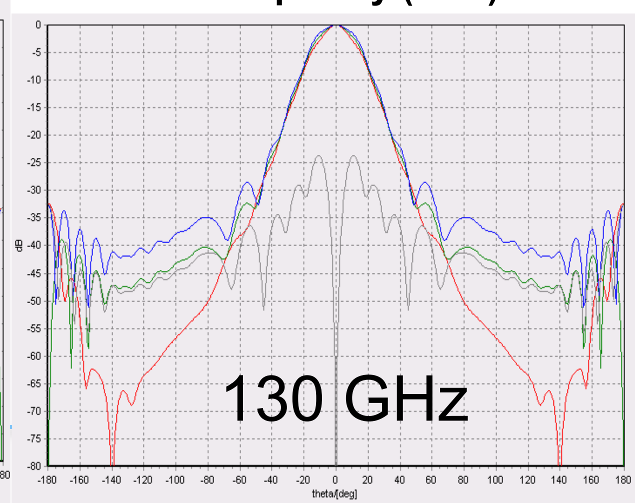


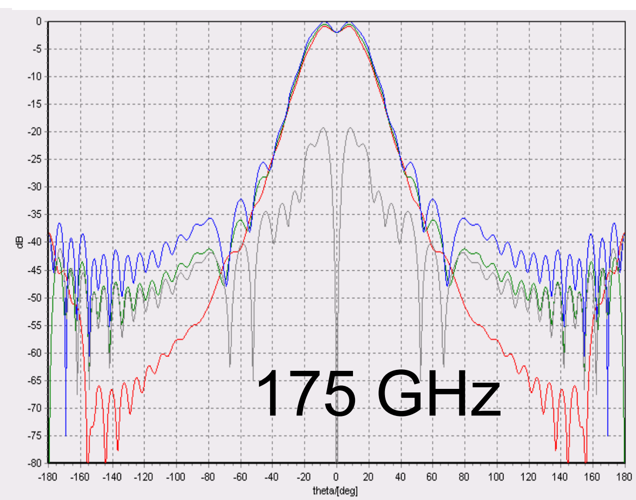
Feed Horn and Triplexer Simulated Performance



Bandwidth of
11 GHz at 92 GHz

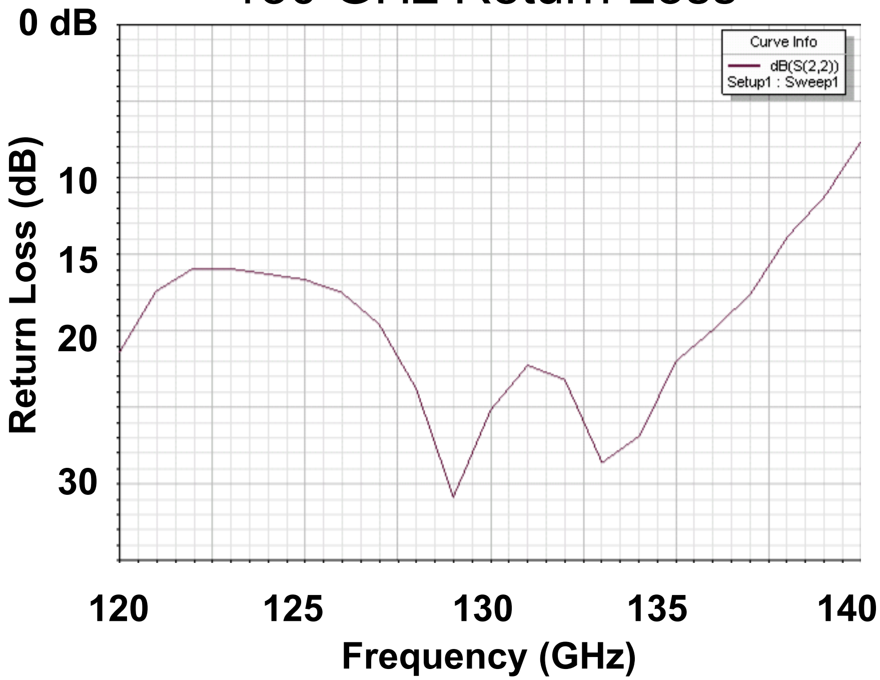




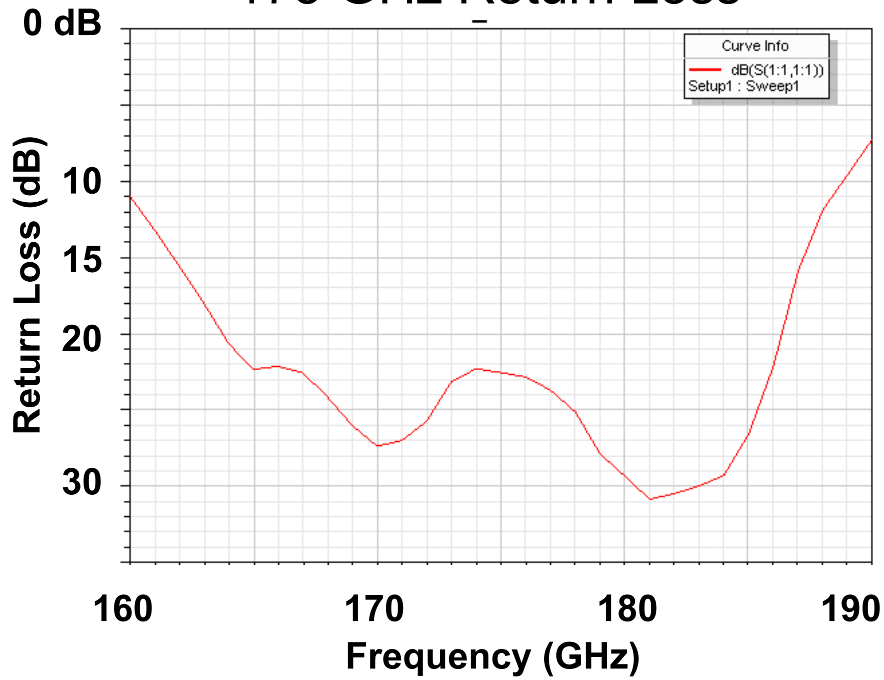


Feed Horn and Triplexer Simulated Performance

130 GHz Return Loss



175 GHz Return Loss



Bandwidth of 17.5 GHz at 130 GHz

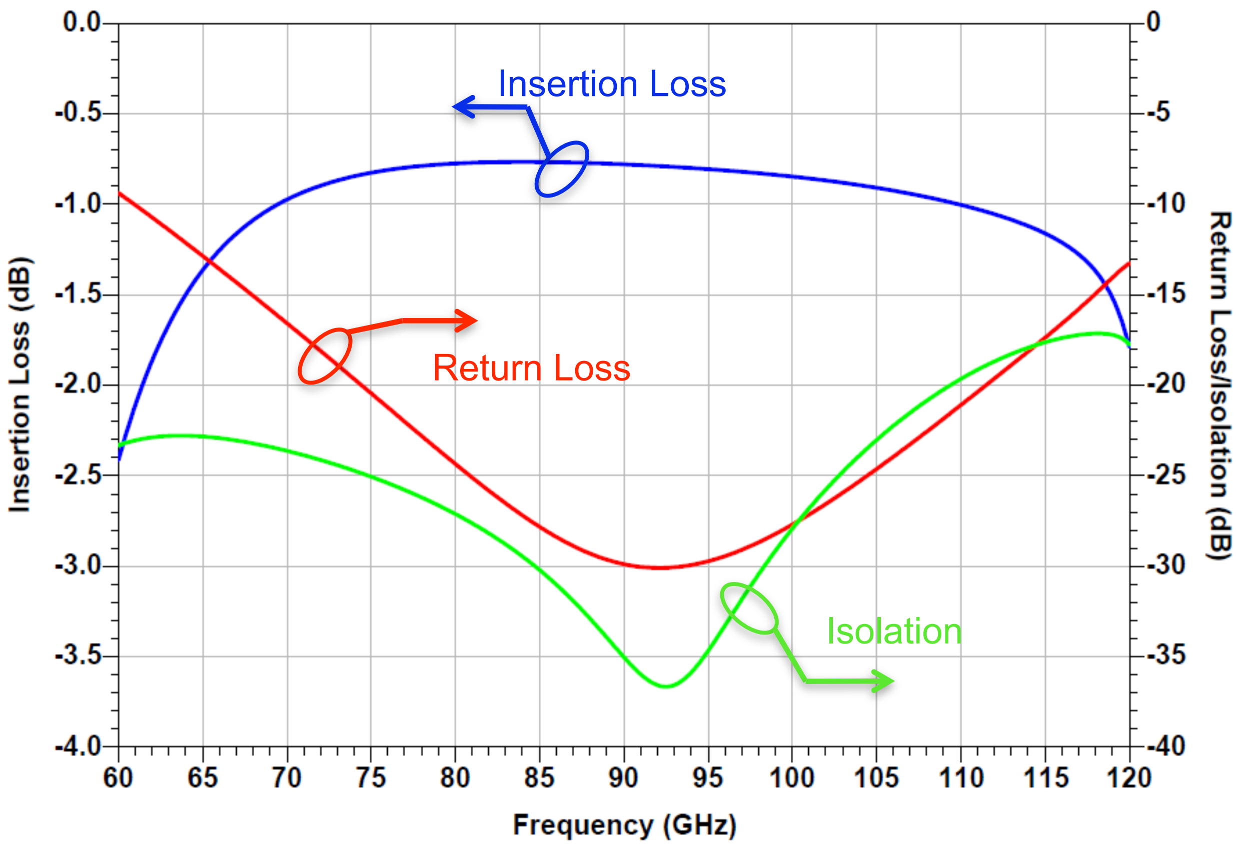
Bandwidth of 25 GHz at 175 GHz

PIN-Diode Switch Design Goals

- Radiometric objectives
  - Provide a method for switching the radiometer from viewing an external scene to viewing an internal reference.
    - Frequent calibration minimizes gain fluctuations to increase stability
- Desired RF characteristics from radiometer requirements
  - Low insertion loss: minimizes impact on overall system noise
  - High return loss: minimizes standing waves that increase calibration difficulty
  - High isolation: eliminates scene contamination during calibration
  - Stable
  - Good switching speed (~0.1 ms)
- **Current design simulations meet RF objectives for return loss, insertion loss, and isolation.**

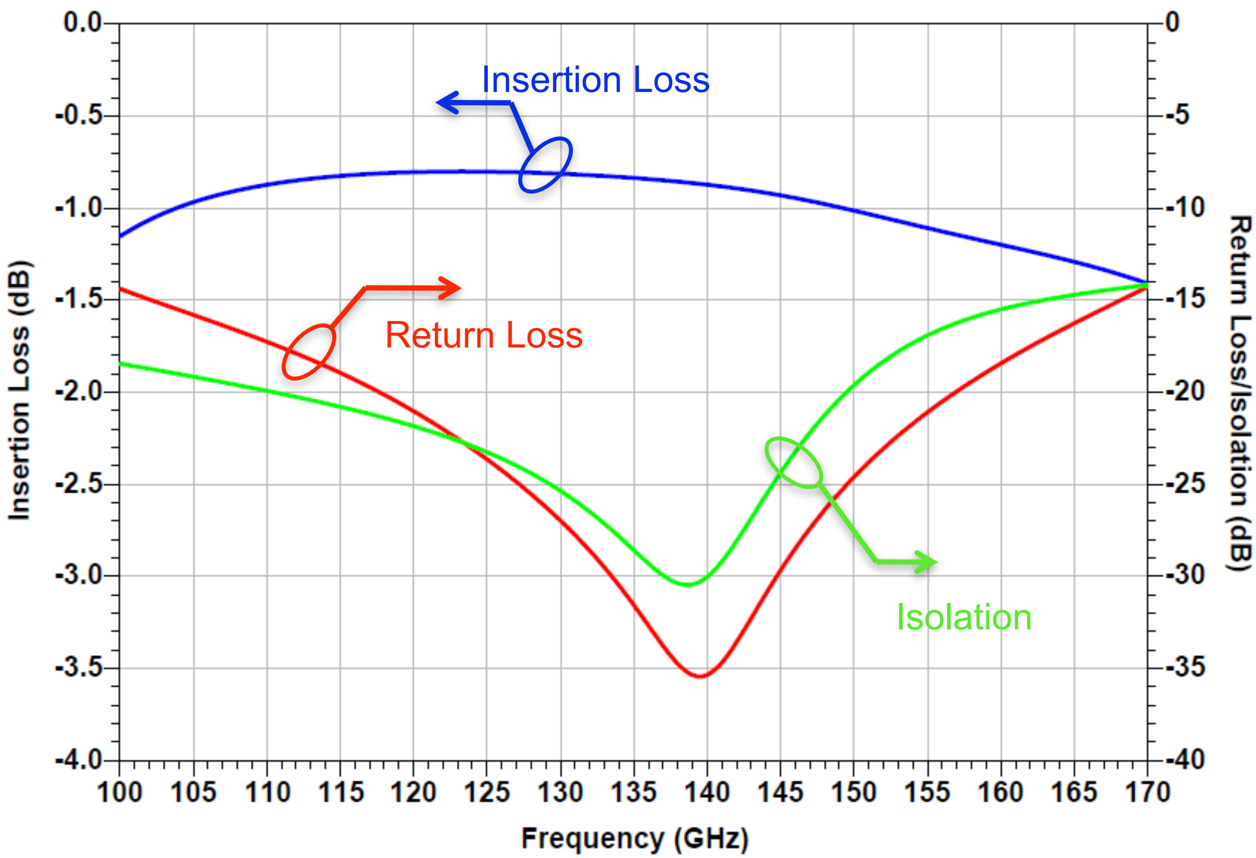
92-GHz MMIC PIN-Diode Switch

92-GHz PIN-Diode Switch Simulation Results



135-GHz MMIC PIN-Diode Switch

135-GHz PIN-Diode Switch Simulation Results



Noise Source Objectives

- Radiometric objectives
  - Provide an electronically-switchable source for calibrating the radiometer over long time scales, i.e. hours to days.
- RF objective
  - Stable Excess Noise Ratio (ENR) large enough to be useful in coupled noise configuration (~10 dB ENR or higher).

- **Current design meets RF objectives at 92 GHz, and simulations show that current components can potentially meet objectives at 130 and 166 GHz.**

Noise Diodes Measured to Date

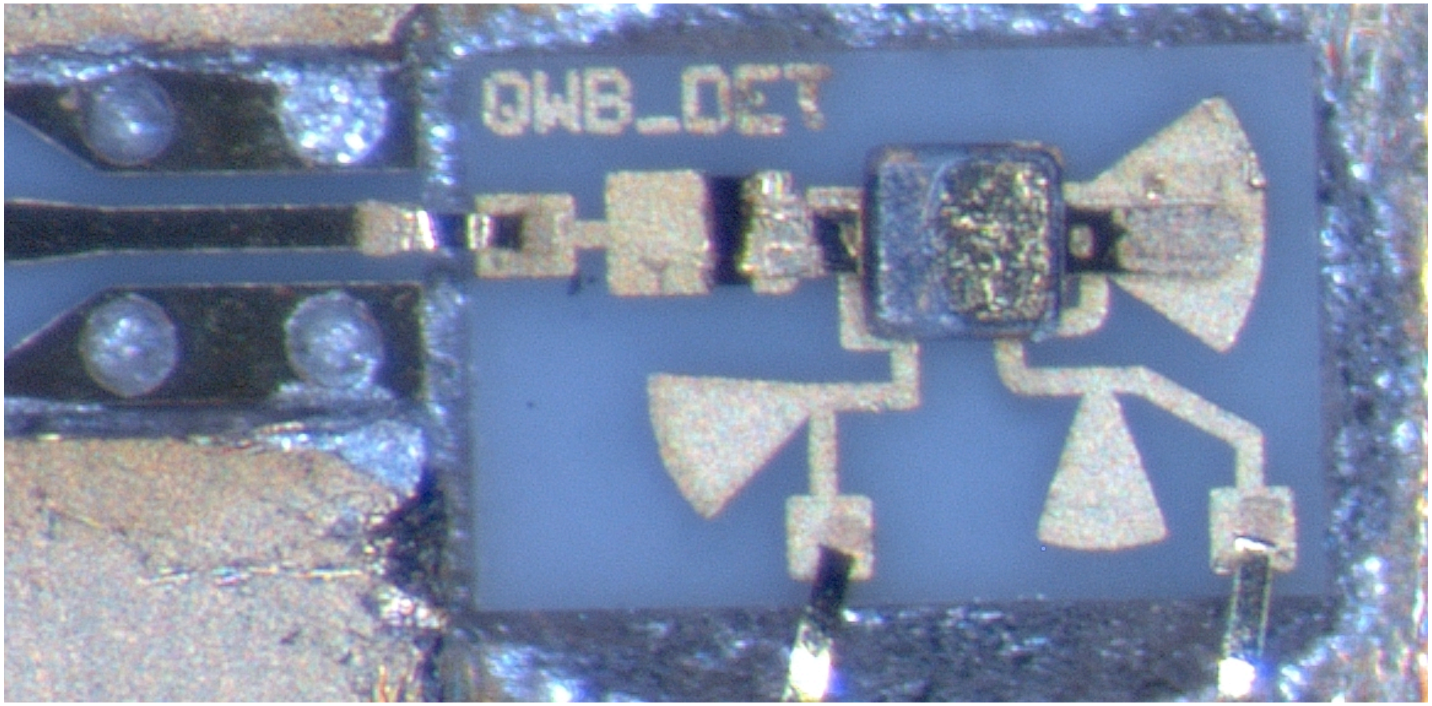
Package Style	Manufacturer	ENR @ 90 GHz (dB)	ENR @ 120 GHz (dB)
Beam Lead*	**M-Pulse**	**13**	**12**
Bare Die (substrate bypass)	**M-Pulse**	**11**	**4**
Bare Die (wire bypass)	**M-Pulse**	**10**	**4**
Bare Die	Micronetics	--	--
Bare Die**	Virginia Diodes	--	--

Bold indicates designs measured as of 2/15/2010.

*Package produced for NASA/GSFC

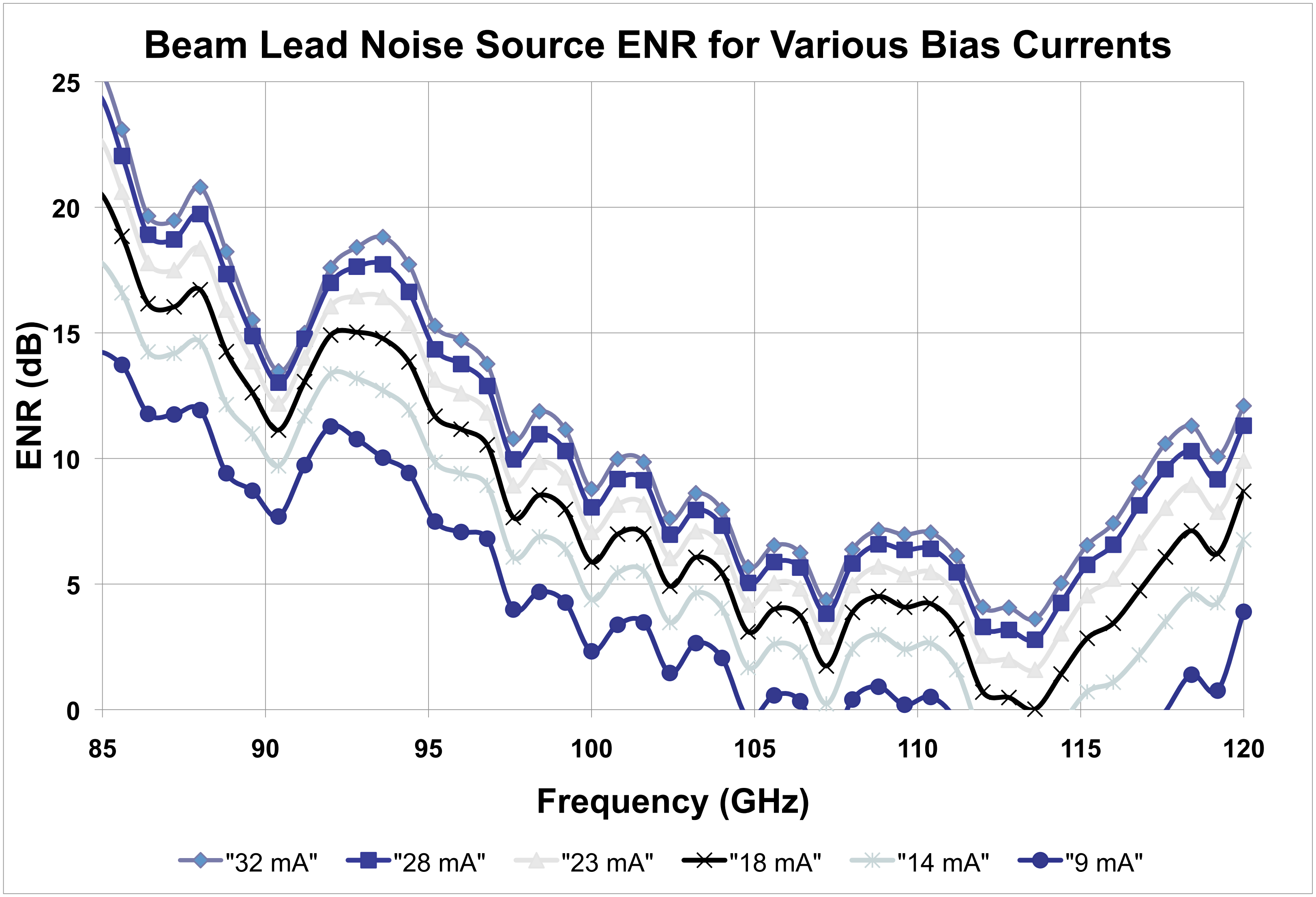
**Die produced through NASA SBIR; none procured at JPL to date

Measured Noise Diode Package

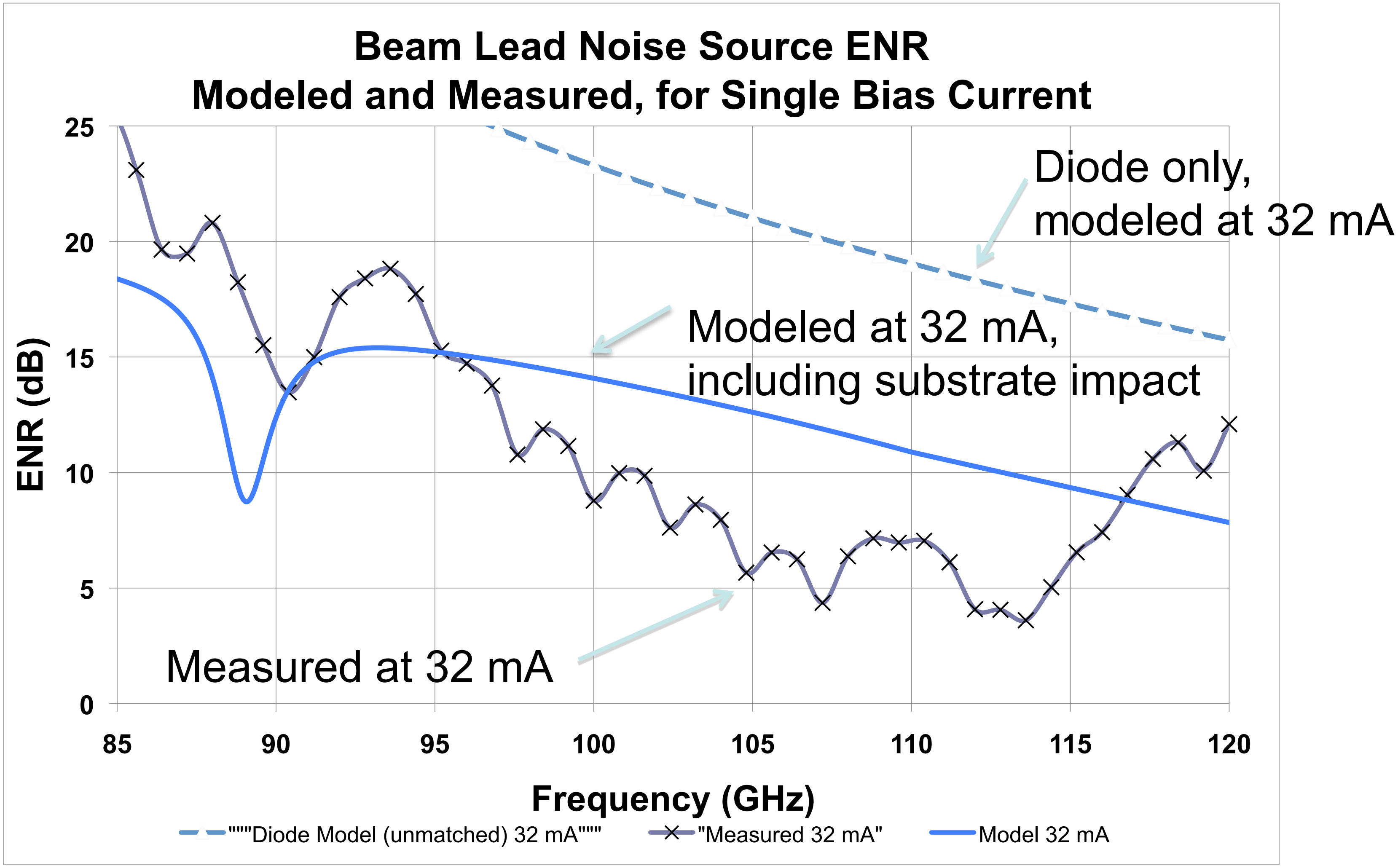


Initial packaging of beam lead diode in available waveguide-to-microstrip chassis using existing substrates

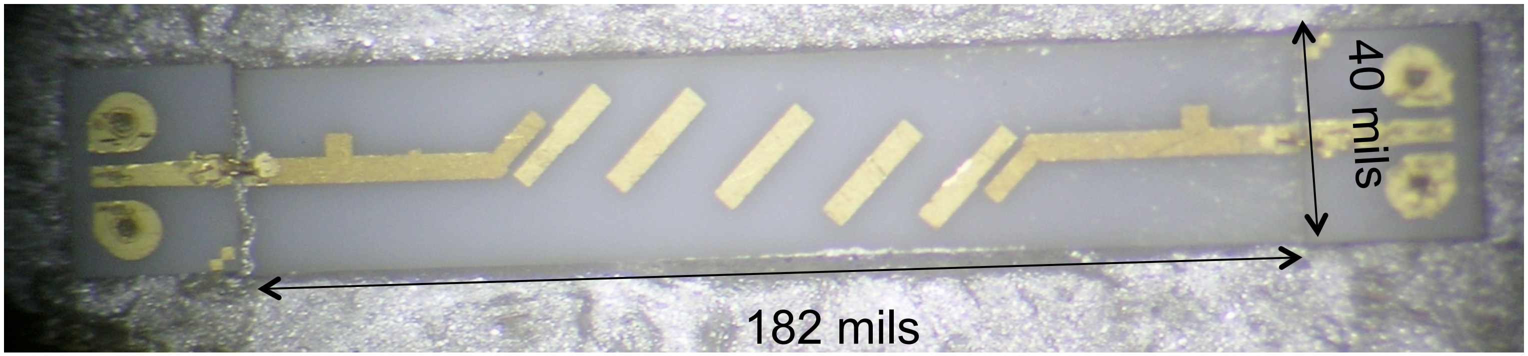
Measured Noise Source Data

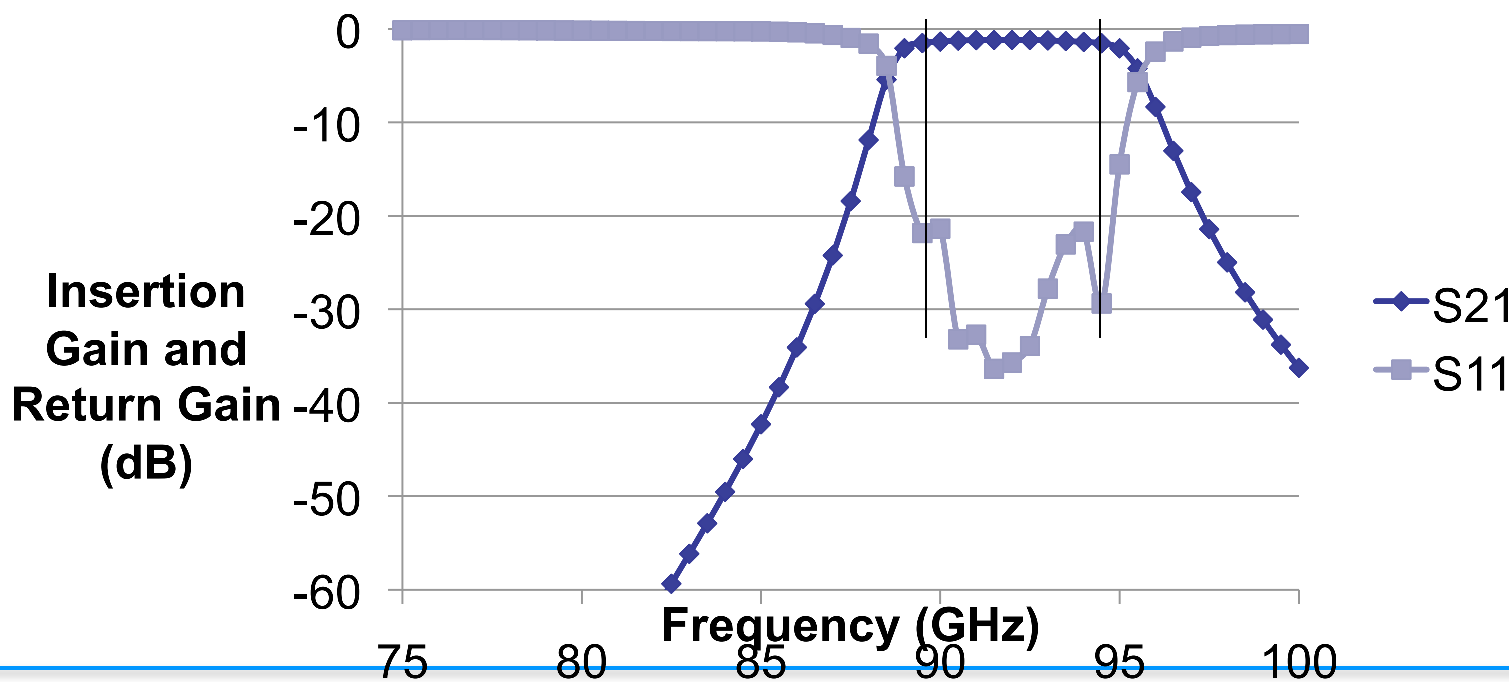


Measured vs. Current Model

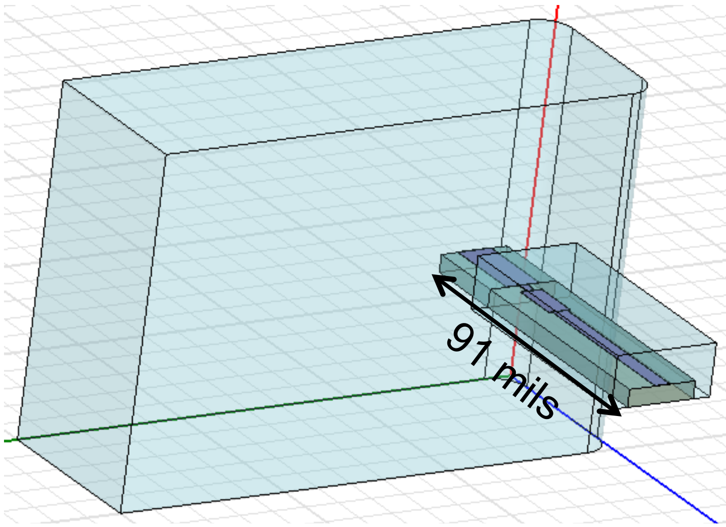


Bandpass Filter Design

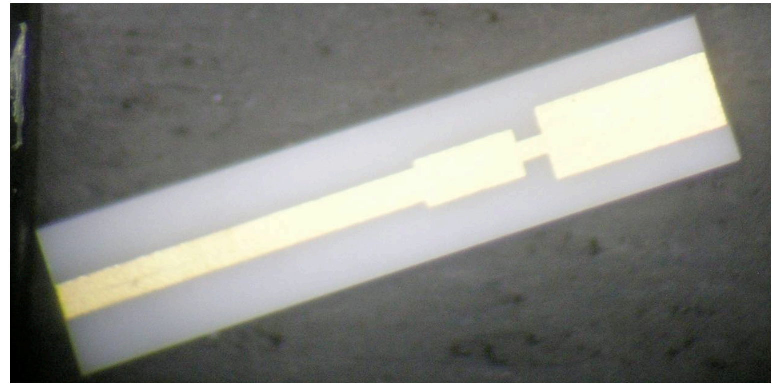




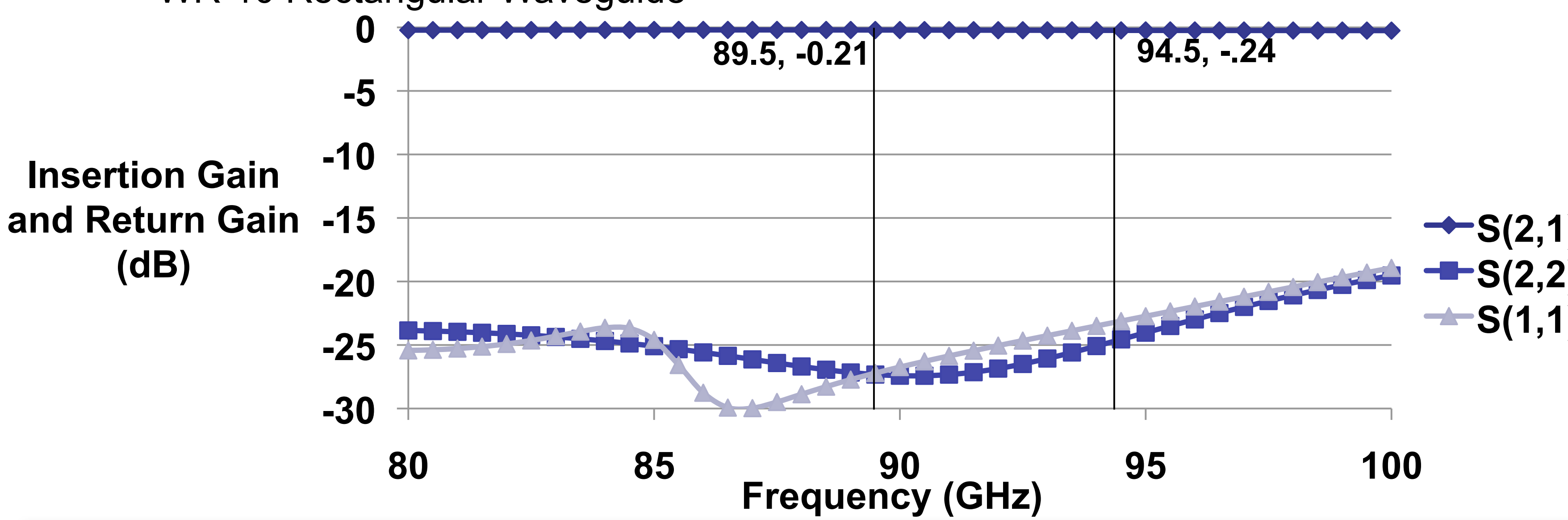
Waveguide-to-Microstrip Transition



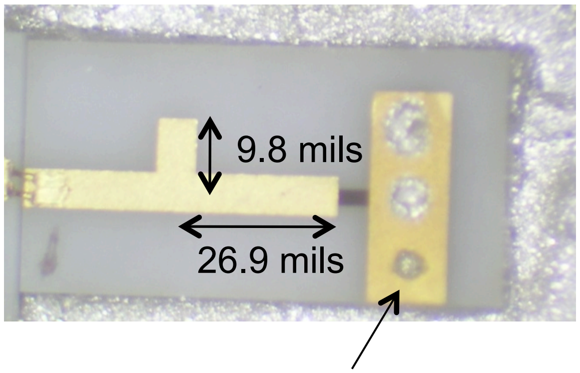
WR-10 Rectangular Waveguide



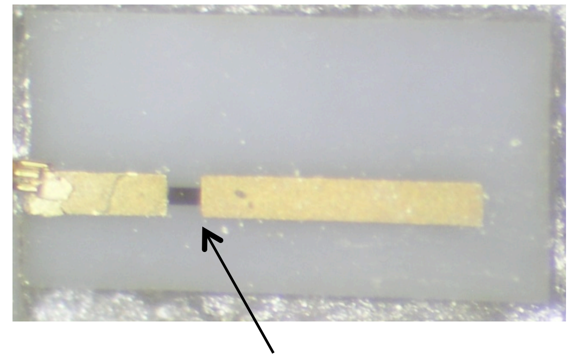
*Y.-C. Leong and S. Weinreb, “Full Band Waveguide-to- Microstrip Probe Transitions,” IEEE MTT-S Digest, pp. 1435-1438, 1999.



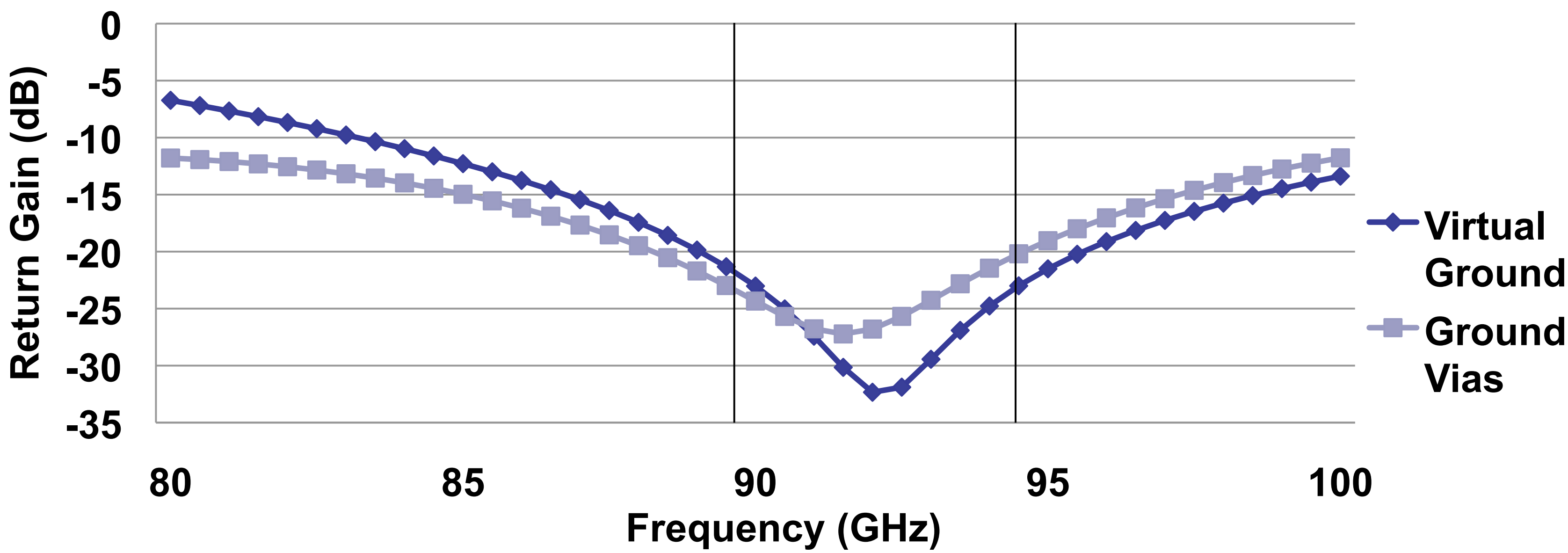
Ambient Matched Load Designs



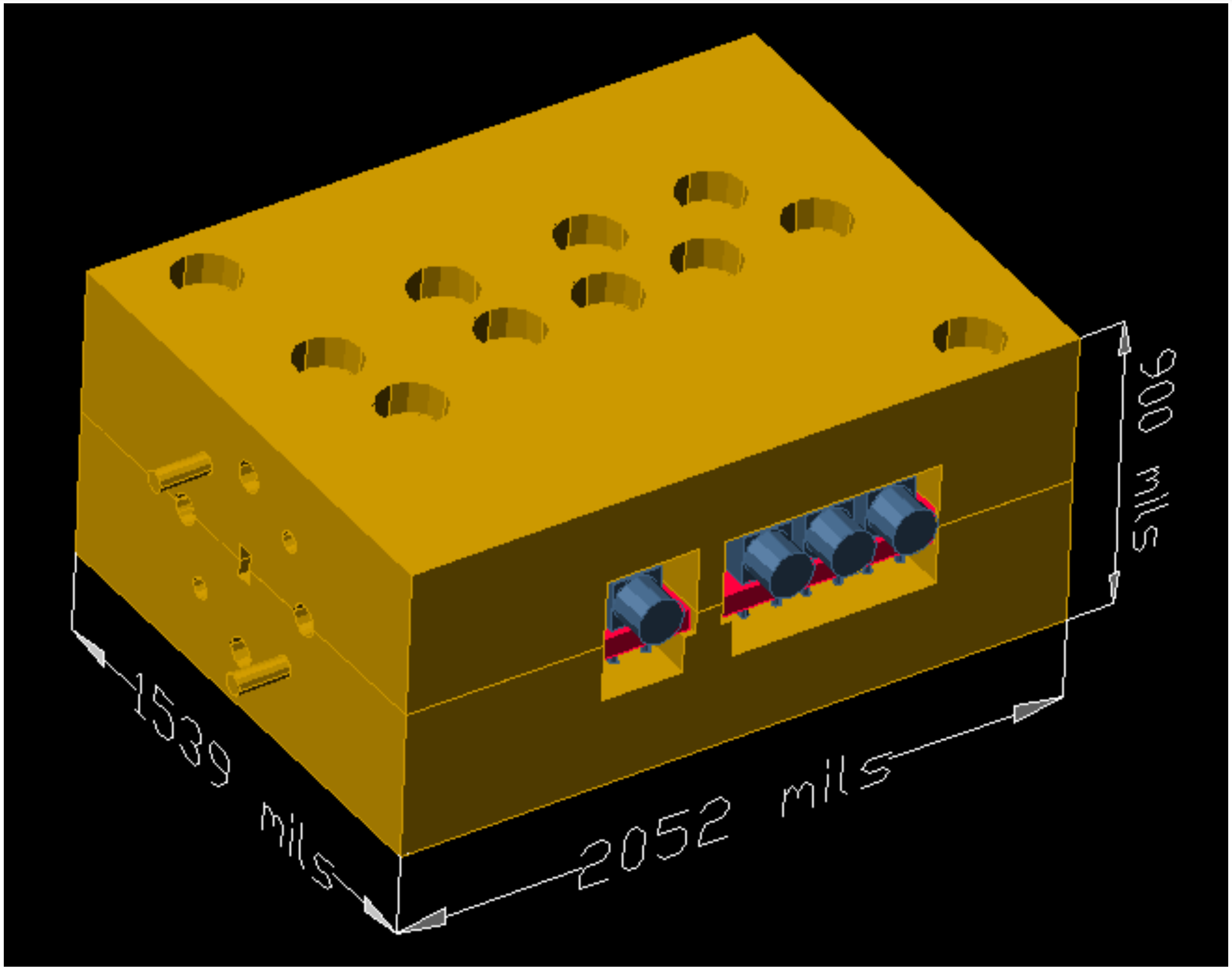
Grounded Vias



Virtual Ground

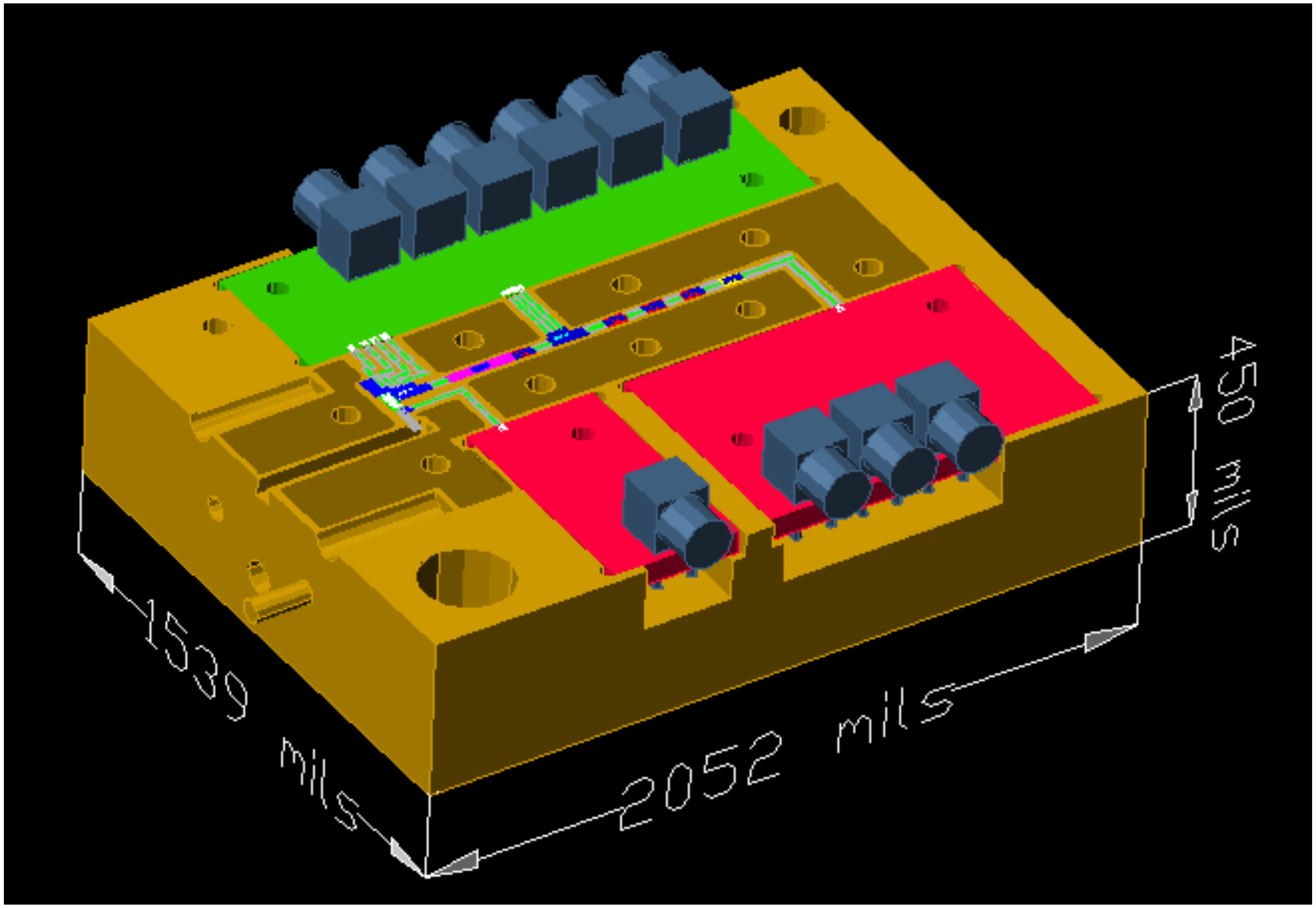


92-GHz Multi-Chip Module Design



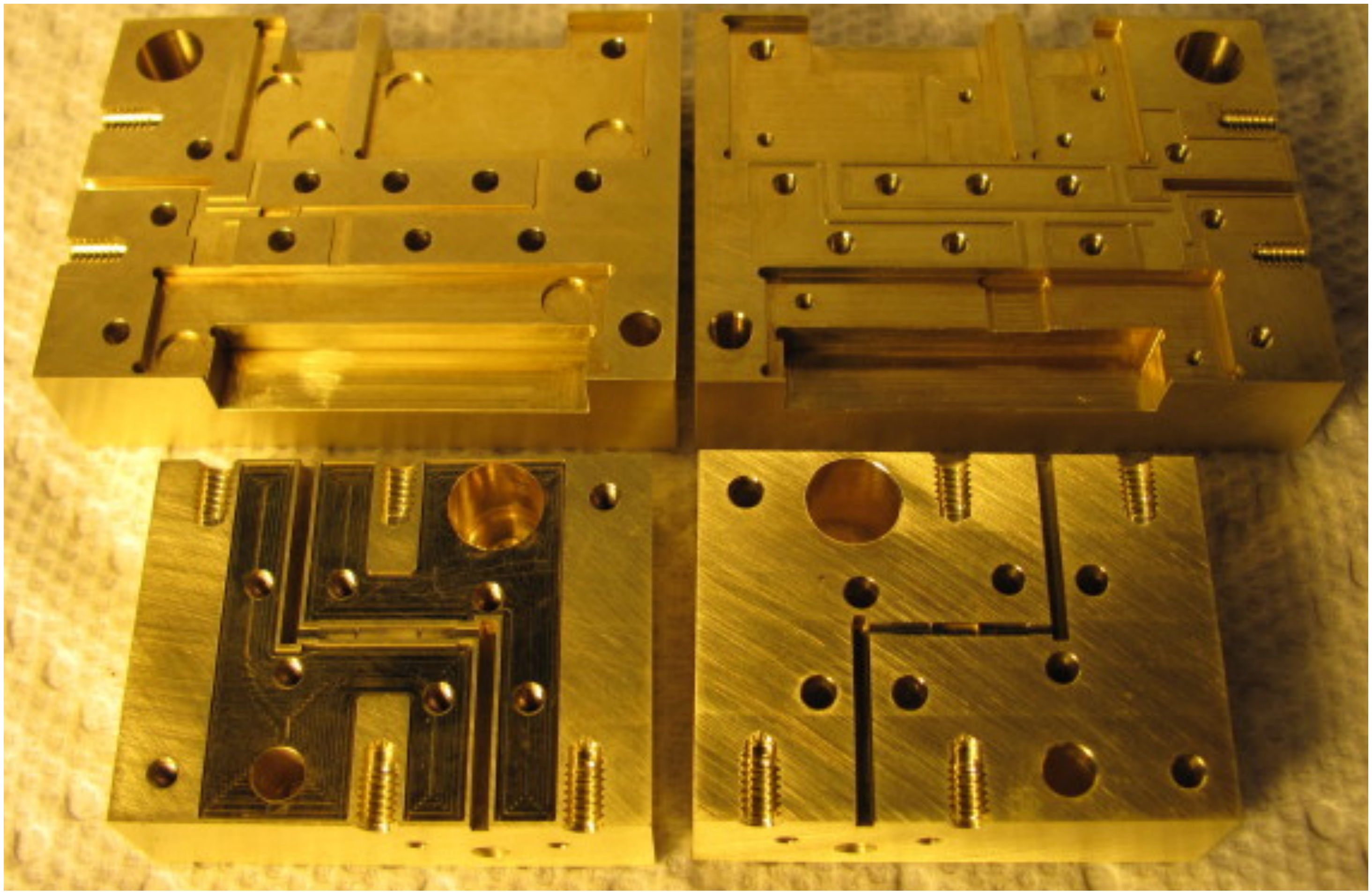
Front view of MCM with lid on

92-GHz Multi-Chip Module Design



MCM bottom clamshell

92-GHz Multi-Chip Module



Summary

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- Addition of higher-frequency microwave channels to Jason-class radiometer will improve retrievals in coastal regions and may enable retrievals over land.
- To this end, we are developing low-power, low-mass and small-volume direct-detection millimeter wave receivers with integrated calibration sources as well as a tri-frequency feed horn covering 90 to 170 GHz.
- We are fabricating and testing a MMIC-based low-mass, low-power, small-volume radiometer with channels at 92, 130 and 166 GHz integrated with a tri-frequency feed horn.

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